

WHAT IS CLAIMED IS:

[c01] A phosphor comprising: (a) at least a first metal selected from the group consisting of yttrium and elements of lanthanide series other than europium; (b) at least a second metal selected from the group consisting of aluminum, gallium, indium, and scandium; (c) boron; and (d) europium.

[c02] A phosphor having a formula of $(D_{1-x}Eu_x)A_3B_4O_{12}$; wherein D is at least a metal selected from the group consisting of yttrium and elements of the lanthanide series other than europium; A is at least a metal selected from the group consisting of aluminum, gallium, indium, and scandium; and x is in a range from about 0.001 to about 0.3.

[c03] The phosphor according to claim 2, wherein x is in a range from about 0.01 to about 0.2.

[c04] The phosphor according to claim 2, wherein D is at least a metal selected from the group consisting of Y, La, Ce, Pr, Sm, Gd, Tb, and Lu.

[c05] The phosphor according to claim 2, wherein D is at least a metal selected from the group consisting of Y, La, Gd, and Lu.

[c06] The phosphor according to claim 2, wherein D is a combination of Y and Gd, and A is Al.

[c07] The phosphor according to claim 2, wherein D is a combination of Y and Gd, and A is a combination of Al, Sc, and Ga.

[c08] A phosphor blend comprising: (a) a phosphor having a formula of $(D_{1-x}Eu_x)A_3B_4O_{12}$; wherein D is at least a metal selected from the group consisting of yttrium and elements of the lanthanide series other than europium; A is at least a metal selected from the group consisting of aluminum, gallium, indium, and scandium; and x is in a range from about 0.001 to about 0.3; (b) a green light-emitting phosphor; and (c) a blue light-emitting phosphor.

[c09] The phosphor blend according to claim 8, wherein x is in a range from about 0.01 to about 0.2.

[c10] The phosphor blend according to claim 8, wherein D is at least a metal selected from the group consisting of Y, La, Ce, Pr, Sm, Gd, Tb, and Lu.

[c11] The phosphor blend according to claim 8, wherein D is at least a metal selected from the group consisting of Y, La, Gd, and Lu.

[c12] The phosphor blend according to claim 8, wherein D is a combination of Y and Gd, and A is Al.

[c13] The phosphor blend according to claim 8, wherein D is a combination of Y and Gd, and A is a combination of Al, Sc, and Ga.

[c14] The phosphor blend according to claim 8; wherein the green light-emitting phosphor is selected from the group consisting of $\text{LaPO}_4\text{:Ce}^{3+}, \text{Tb}^{3+}$; $\text{GdMgB}_5\text{O}_{10}\text{:Ce}^{3+}, \text{Tb}^{3+}$; $\text{CeMgAl}_{11}\text{O}_{19}\text{:Ce}^{3+}, \text{Tb}^{3+}$; $\text{Ca}_5(\text{PO}_4)_3(\text{Cl}, \text{F}, \text{OH})\text{:Sb}^{3+}, \text{Mn}^{2+}, \text{Eu}^{2+}$; $\text{Sr}_4\text{Al}_{14}\text{O}_{25}\text{:Eu}^{2+}$; and $\text{BaAl}_8\text{O}_{13}\text{:Eu}^{2+}$; and combinations thereof.

[c15] The phosphor blend according to claim 8, wherein the blue light-emitting phosphor is selected from the group consisting of $(\text{Ba}, \text{Sr}, \text{Ca})\text{MgAl}_{10}\text{O}_{17}\text{:Eu}^{2+}$; $(\text{Ba}, \text{Sr}, \text{Ca})_5(\text{PO}_4)_3(\text{Cl}, \text{F}, \text{OH})\text{:Eu}^{2+}$; $(\text{Ba}, \text{Sr}, \text{Ca})\text{BPO}_5\text{:Eu}^{2+}$; and combinations thereof.

[c16] A method for making a phosphor, the method comprising:

(a) mixing oxygen-containing compounds of:

(1) at least a first metal selected from the group consisting of yttrium and elements of lanthanide series other than europium;

(2) at least a second metal selected from the group consisting of aluminum, gallium, indium, and scandium;

(3) boron; and

(4) europium to form a mixture; and

(b) heating the mixture in an oxygen-containing atmosphere at a temperature in a range from about 900 C to about 1400 C for a time sufficient to convert the mixture to the phosphor.

[c17] The method according to claim 16, wherein the phosphor has a formula of $(D_{1-x}Eu_x)A_3B_4O_{12}$; wherein D is at least a metal selected from the group consisting of yttrium and elements of the lanthanide series other than europium; A is at least a metal selected from the group consisting of aluminum, gallium, indium, and scandium; and x is in a range from about 0.001 to about 0.3.

[c18] The method according to claim 17, wherein the oxygen-containing compound of boron H_3BO_3 , and an amount of H_3BO_3 in the mixture is in excess of stoichiometric amount.

[c19] The method according to claim 18, further comprising washing the phosphor after heating to remove excess boron compound.

[c20] A method of preparation of a phosphor, the method comprising:

(a) providing a first solution that comprises:

(1) at least a compound of at least a first element selected from the group consisting of yttrium and elements of lanthanide series other than europium;

(2) at least a compound of at least a second element selected from the group consisting of aluminum, gallium, indium and scandium;

(3) at least a compound of boron; and

(4) at least a compound of europium;

(b) adding a second solution to the first solution to produce a precipitate comprising compounds of the first element, the second element, boron, and europium; the second solution comprising a base selected from the group consisting of ammonium hydroxide; hydroxides of at least one element selected from the group consisting of yttrium, elements of lanthanide series; organic esters of carboxylic acids; organic amines; and combinations thereof; and

(c) heating the precipitate in an oxygen-containing atmosphere at a temperature in a range from about 900 C to about 1400 C for a time sufficient to convert the precipitate to the phosphor.

[c21] A light source comprising:

(a) a source of UV radiation that is located in a sealed housing; and

(b) a phosphor disposed within the sealed housing and adapted to be excited by the UV radiation and to emit visible light, wherein the phosphor comprises:

(1) at least a first metal selected from the group consisting of yttrium and elements of lanthanide series other than europium;

(2) at least a second metal selected from the group consisting of aluminum, gallium, indium, and scandium;

(3) boron; and

(4) europium.

[c22] The light source according to claim 21, wherein the phosphor has a formula of $(D_{1-x}Eu_x)A_3B_4O_{12}$; wherein D is at least a metal selected from the group consisting of yttrium and elements of the lanthanide series other than europium; A is

at least a metal selected from the group consisting of aluminum, gallium, indium, and scandium; and x is in a range from about 0.001 to about 0.3.

[c23] The light source according to claim 22, wherein x is in a range from about 0.01 to about 0.2.

[c24] The light source according to claim 22, wherein D is at least a metal selected from the group consisting of Y, La, Ce, Pr, Sm, Gd, Tb, and Lu.

[c25] The light source according to claim 22, wherein D is at least a metal selected from the group consisting of Y, La, Gd, and Lu.

[c26] The light source according to claim 22, wherein D is a combination of Y and Gd, and A is Al.

[c27] The light source according to claim 22, wherein D is a combination of Y and Gd, and A is a combination of Al, Sc, and Ga.

[c28] The light source according to claim 21, wherein the source of UV radiation is a mercury vapor discharge.

[c29] The light source according to claim 21, further comprising at least a green light-emitting phosphor selected from the group consisting of $\text{LaPO}_4\text{:Ce}^{3+}, \text{Tb}^{3+}$; $\text{GdMgB}_5\text{O}_{10}\text{:Ce}^{3+}, \text{Tb}^{3+}$; $\text{CeMgAl}_{11}\text{O}_{19}\text{:Ce}^{3+}, \text{Tb}^{3+}$; $\text{Ca}_5(\text{PO}_4)_3(\text{Cl}, \text{F}, \text{OH})\text{:Sb}^{3+}, \text{Mn}^{2+}, \text{Eu}^{2+}$; $\text{Sr}_4\text{Al}_{14}\text{O}_{25}\text{:Eu}^{2+}$; and $\text{BaAl}_8\text{O}_{13}\text{:Eu}^{2+}$; and combinations thereof.

[c30] The light source according to claim 21, further comprising at least a blue light-emitting phosphor selected from the group consisting of $(\text{Ba}, \text{Sr}, \text{Ca})\text{MgAl}_{10}\text{O}_{17}\text{:Eu}^{2+}$; $(\text{Ba}, \text{Sr}, \text{Ca})_5(\text{PO}_4)_3(\text{Cl}, \text{F}, \text{OH})\text{:Eu}^{2+}$; $(\text{Ba}, \text{Sr}, \text{Ca})\text{BPO}_5\text{:Eu}^{2+}$; and combinations thereof.

[c31] A light source comprising:

(a) a source of UV radiation disposed in sealed housing, the UV source comprising a mercury vapor that is capable of absorbing energy of electron to create a mercury vapor discharge; and

(b) a phosphor blend disposed on an inner surface of the sealed housing, the phosphor blend comprises a first phosphor having a formula of $\text{LaPO}_4:\text{Ce}^{3+}, \text{Tb}^{3+}$; a second phosphor having a formula of $(\text{Ba}, \text{Sr}, \text{Ca})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$; and a third phosphor having a formula of $(\text{Y}_{0.9}\text{Eu}_{0.1})\text{Al}_3\text{B}_4\text{O}_{12}$; the phosphor blend absorbing UV radiation from the source of UV radiation and emitting light in a visible range.